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Theoretical Modeling of Web Characteristics on the Needle Punching Production Line

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1. Introduction

Needle punching is a process for converting fiber webs into coherent structures by using barb needles. The results are the mechanical interlocking of fibers into webs. Nonwovens by needle punching is most versatile among the various methods and is widely used in the industry. The original process for the production of mechanical bonds in nonwoven fabrics is that which employs the natural felting characteristics of the wool fiber. Such products are today used in highly specialized applications. The needle punching technique is suitable for the production of a range of products like blankets, filtration media, geotextiles and civil-engineering substrates.

The properties of needle punched nonwovens depend on raw materials used and the needling parameters employed like needling density and depth of needle penetration. By varying the needling parameters in needle punching production line, it is very difficult to achieve the required fabric properties. The variables above are critical to the quality of the fabric produced as well as the efficiency of the needle process.

In order to achieve the required qualities of a needle punched nonwoven fabric, it is necessary to adjust the needle punching machine, or line of these machines, correctly. This is also a condition for reaching the maximum output and optimal service-life of the machines. Therefore, the object of this study is to examine some basic facts concerning with needled fabric dimensions on the needle punching production line.

2. Modeling theory

Figure 1 shows a schematic diagram of needle punching production line for modeling. It is consist of 1 passage of pre-needling and 3 passages of main needling machines. First, the symbols used in the theorization of processing condition are as follows.

F : Punching density of nonwoven(punches/cm^2)
S : Number of strokes of needle beam(strokes/min)
N : Needle density of needle board(#/m)
D : Draft ratio
R_w : The reduction in width(%)
V_1 : Feeding speed of web(m/min)
V_2 : Delivery speed of nonwoven(m/min)
W_1 : The width of web at the feeding end(m)
W_2 : The width of web at the delivery end(m)

A_1 : The areal weight before needle punching(g/m^2)
A_2 : The areal weight after needle punching(g/m^2)

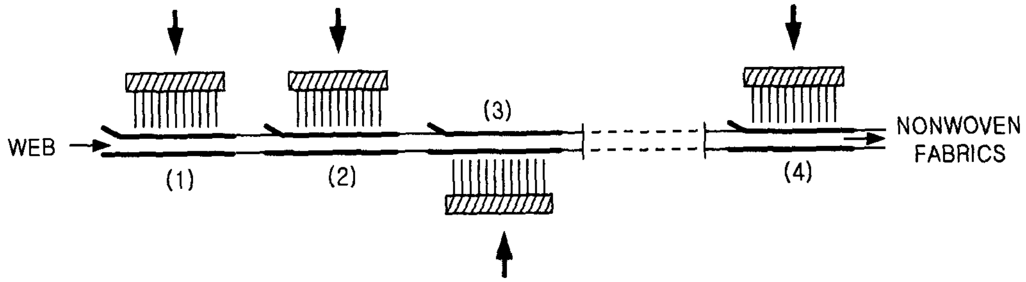

Figure 1 Schematic diagram of the needle punching nonwoven processing.
(1) Pre-needle loom (2) 1st needle loom
(3) 2nd needle loom (4) Finish needle loom

In Figure 1, the penetration of the needle punched fabric after one step punching can be present with formula (1).

$$F = \frac{S_k N_k}{K V_{k+1}} \qquad (k= 1, 2, 3, ..., n) \qquad (1)$$

This relation is valid while needle punching the firm base when no dimensional deformation occurs. For the calculation of longitudinal deformation as well as transverse deformation in production line, it is necessary to use the following formula (2).

$$F = \frac{S_k N_k (A_k + A_{k+1})}{K(V_k + V_{k+1}) A_{k+1} D_k} \qquad (k=1, 2, 3, ..., n) \qquad (2)$$

Therefore, the penetrations of final nonwovens after several punching steps can be present with formula (3).

$$F_n = \sum_{k=1}^{n} \frac{S_k N_k (A_k + A_{k+1})}{K(V_k + V_{k+1}) A_{k+1} D_k} \qquad (k=1, 2, 3, ..., n) \qquad (3)$$

Also, to calculate the required fabric areal weights before needle punching, we can use the formula (4) for a given punching line.

$$W_k = D_k W_{k+1} \frac{A_{k+1}}{A_k} \qquad (k=1, 2, 3, ..., n) \qquad (4)$$

Further, we calculate the necessary fabric width before a given needle punching line according to the formula (5).

$$W_k = \frac{W_{k+1} 100}{100 - R_w} \qquad (k=1, 2, 3, ..., n) \qquad (5)$$

3. Experimental

The fiber used in this study was polypropylene with 47.5mm fiber length and a denier of 2. A carded and cross-lapped webs were doubled various times by web forming machine as possible punching operation. This web was needle-punched using needle loom which is shown in Figure 1. The conditions of each needling part used in the experimental are given in Table 1.

Table 1 Needle loom conditions used in the experimental

Item / Series	Feeding speed (m/min)	Delivery speed (m/min)	strokes (rpm/min)	No. of needle (#/m)	Penetration depth(mm)
Pre-needle loom	1.55	1.95	250	5,000	11
1st needle loom	1.95	2.45	600	10,000	10
2nd needle loom	2.45	2.85	450	15,000	7
Finish needle loom	2.85	3.05	480	15,000	6

Since we expected the width reduction of web to influence needling due to web draft, we can predict the width of the needled fabrics in each needling step. To accomplish this, we made a small mark on each web between forming machine and needle punching machine, and then collected data after the mark passed through the delivery roller on the machine.

4. Results and Discussion

The optimum strokes can determine the mechanical properties and production speed of needle punching nonwovens and has influenced over the amount of fibers pushed by the needle in each stroke.

Figure 2 shows the punching density by needle punching production line which is the results of calculation by using formula (1) and (2). Generally, needle punching density as expected, increased with increasing in the number of strokes and needle density. And, as plotted to Figure 2, if we take account of longitudinal deformation and transverse deformation which were practically lower. This reduction may be partly due to a drafting action, giving an increase in length, as the web is dragged through the gap between the bed and stripper plates.

Figure 3 shows the results of reduction in fabric width according to needle punching. This is because the fibers in the web were affected on the continuous needling and the improved interlocking of fibers achieved at higher strokes makes the fabric more compact.

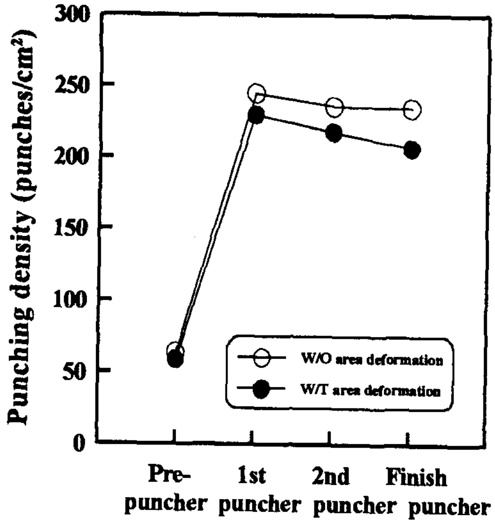

Figure 2 Punching density according to the needle loom construction.

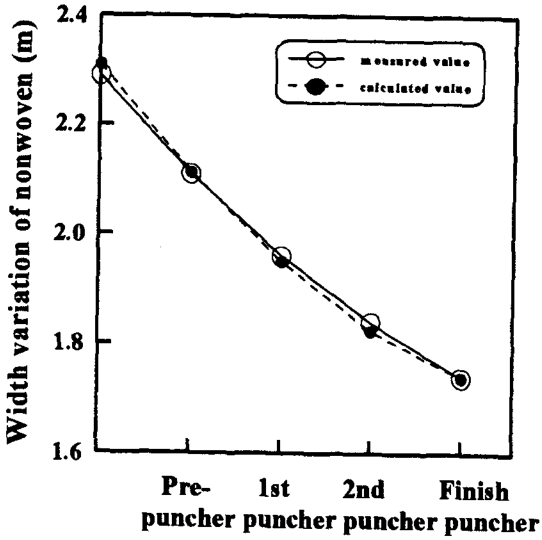

Figure 3 The comparison of width variation by the measured and calculated value.

5. Conclusions

We have studied an theoretical modeling of needle punching nonwovens with respect to machine parameters and also considered their effect on the number of strokes, width reduction, and areal density. The conclusions obtained in this study are as follows.

1) Punching density per unit area has increased with increasing the number of strokes. and it has been decreased by changing a longitudinal deformation and transverse deformation with the passage of a needle loom.
2) The width of nonwoven has reduced with increasing the number of needling. And this value between theoretical and experiment is a little different, but the theoretical value obtained from modeling can be good fitted

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